Property Library for Tetradecamethyl-hexasiloxane (MD4M) $C_{14}H_{42}O_5Si_6$

FluidEXL *Graphics* with LibMD4M for Excel®

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Software for the Calculation of the Properties
of Tetradecamethylhexasiloxane (MD4M)
Including DLL and Add-In for Excel®

FluidEXL *Graphics*
LibMD4M

Contents

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0 Package Contents

0.1   Zip files for 64-bit Office®

The following zip file has been delivered for your computer running a 64-bit Office® version:

   CD_FluidEXL_Graphics_Eng_LibMD4M_x64.zip

including the following folders an files:

   \FLUFT\

   \Formulation97\

   FluidEXL_Graphics_LibMD4M_Docu_Eng.pdf

   FluidEXL_Graphics_Eng.xla

   LC.dll

   LibMD4M.dll

   LibMD4M.chm.

0.2   Zip files for 32-bit Office®

The following zip file has been delivered for your computer running a 32-bit Office® version:

   CD_FluidEXL_Graphics_Eng_LibMD4M.zip

including the following folders and files:

   \FLUFT\

   \Formulation97\

   FluidEXL_Graphics_LibMD4M_Docu_Eng.pdf

   FluidEXL_Graphics_Eng.xla

   LC.dll

   LibMD4M.dll

   LibMD4M.chm.

1. Property Functions

1.1 Calculation Programs

"MD4M" means Tetradecamethylhexasiloxane ($C_{14}H_{42}O_5Si_6$)

Functional Dependence	Function Name	Call from Fortran program	Property or Function	Unit of the result
$c_p = f(p,t,x)$	cp_ptx_MD4M	CPPTXMD4M(P,T,X)	Specific isobaric heat capacity	kJ/(kg K)
$c_v = f(p,t,x)$	cv_ptx_MD4M	CVPTXMD4M(P,T,X)	Specific isochoric heat capacity	kJ/(kg K)
$\left(\dfrac{\partial p}{\partial T}\right)_v = f(p,t,x)$	dpdtv_ptx_MD4M	DPDTVMD4M(P,T,X)	Derivative of pressure with respect to temperature (at constant specific volume)	kPa/K
$\left(\dfrac{\partial p}{\partial v}\right)_T = f(p,t,x)$	dpdvt_ptx_MD4M	DPDVTMD4M(P,T,X)	Derivative of pressure with respect to specific volume (at constant temperature)	kPa/(m³/kg)
$\eta = f(p,t,x)$	eta_ptx_MD4M	ETAPTXMD4M(P,T,X)	Dynamic viscosity	Pa·s
$h = f(p,t,x)$	h_ptx_MD4M	HPTXMD4M(P,T,X)	Specific enthalpy	kJ/kg
$\kappa = f(p,t,x)$	kappa_ptx_MD4M	KAPPAPTXMD4M(P,T,X)	Isentropic exponent	-
$\lambda = f(p,t,x)$	lamda_ptx_MD4M	LAMPTXMD4M(P,T,X)	Thermal conductivity	W/(m·K)
$\nu = f(p,t,x)$	nu_ptx_MD4M	NUPTXMD4M(P,T,X)	Kinematic viscosity	m²/s
$p_s = f(t)$	ps_t_MD4M	PSTMD4M(T)	Vapor pressure from temperature	bar
$\rho = f(p,t,x)$	rho_ptx_MD4M	RHOPTXMD4M(P,T,X)	Density	kg/m³
$s = f(p,t,x)$	s_ptx_MD4M	SPTXMD4M(P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	t_ph_MD4M	TPHMD4M(P,H)	Backward function: Temperature from pressure and enthalpy	°C
$t = f(p,s)$	t_ps_MD4M	TPSMD4M(P,S)	Backward function: Temperature from pressure and entropy	°C
$t_s = f(p)$	ts_p_MD4M	TSPMD4M(P)	Saturation temperature from pressure	°C
$u = f(p,t,x)$	u_ptx_MD4M	UPTXMD4M(P,T,X)	Specific internal energy	kJ/kg
$v = f(p,t,x)$	v_ptx_MD4M	VPTXMD4M(P,T,X)	Specific volume	m³/kg
$w = f(p,t,x)$	w_ptx_MD4M	WPTXMD4M(P,T,X)	Isentropic speed of sound	m/s
$x = f(p,h)$	x_ph_MD4M	XPHMD4M(P,H)	Backward function: Vapor fraction from pressure and enthalpy	kg/kg

Functional Dependence	Function Name	Call from Fortran program	Call in DLL LibMD4M as parameter	Property or Function	Unit of the result
$x = f(p,s)$	x_ps_MD4M	XPSMD4M(P,S)	C_XPSMD4M(X,P,S)	Backward function: Vapor fraction from pressure and entropy	kg/kg
$Z = f(p,t,x)$	Z_ptx_MD4M	ZPTXMD4M(P,T,X)	C_ZPTXMD4M(W,P,T,X)	Compression factor	-

Units: t in °C

p in bar

x in (kg of saturated steam)/(kg wet steam)

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Reference state

h = 0 kJ/kg and s = 0 kJ/(kg K) at t_B = 259.573 °C on the boiling curve (x = 0; p_s = p_N = 1.01325 bar)

Details on the vapor fraction *x* and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

<u>Single-phase region</u>

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = −1 must be entered as a pro-forma value.

<u>Wet-steam region</u>

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for *x*. When calculating wet steam either the given value for *t* <u>and</u> p = -1000 or the given value for *p* <u>and</u> t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program considers *p* and *t* to be appropriate to represent the vapor pressure curve. If this is not the case the calculation for the property of the chosen function results in −1000.

Wet steam region: Temperature range from t = 26.85 °C to t_c = 379.05 °C

Pressure range from p_s (26.85 °C) = 0.00001093377 bar to p_c = 8.7747391 bar

Note.

If the calculation results in −1000, the values entered represent a state point beyond the range of validity of MD4M. For further information on each function and its range of validity see Chapter 3. The same information may also be accessed via the online help pages.

2. Application of FluidEXL *Graphics* in Excel®

The FluidEXL *Graphics* Add-In has been developed to calculate thermodynamic properties in Excel® more conveniently. Within Excel®, it enables the direct call of functions relating to Water and Steam from the LibMD4M property program library.

2.1 Installing FluidEXL *Graphics*

Complete the following steps for initial installation of FluidEXL *Graphics*.

Before you begin, it is best to uninstall any older version of FluidEXL *Graphics*.

The installation routine for 32-bit and 64-bit versions of Excel is similar. The following instructions are valid for both versions.

After you have downloaded and extracted the zip-file:

   CD_FluidEXL_Graphics_LibMD4M_x64_Eng.zip   (for 64 bit version)

or

   CD_FluidEXL_Graphics_LibMD4M_Eng.zip"   (for 32 bit version).

you will see the folder

   \CD_FluidEXL_Graphics_LibMD4M_x64_Eng\   (for 64 bit version)

or

   \CD_FluidEXL_Graphics_LibMD4M_Eng\   (for 32 bit version)

in your Windows Explorer, Total Commander etc.

Now, open this folder by double-clicking on it.

Within this folder you will see the following folders and files:

   \FLUFT\
   \Formulation97\
   FluidEXL_Graphics_Eng.xla
   FluidEXL_Graphics_LibMD4M_Docu_Eng
   LC.dll
   LibMD4M.dll
   LibMD4M.chm
   Reg_.reg

Now, please copy the following folders and files

   \FLUFT\
   \Formulation97\
   FluidEXL_Graphics_Eng.xla
   LibMD4M.dll
   LibMD4M.chm
   LC.dll

into the folder

   C:\Users\[your name]\AppData\Roaming\Microsoft\AddIns\,

where [your name] is your name in the Windows system.

If this folder is not found, follow the next section anyway.

2.2   Registering FluidEXL*Graphics* as Add-In in Excel®

After installation in Windows®, FluidEXL*Graphics* must be registered in Excel® as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the "File" button in the upper left hand corner of Excel® (see Fig. 2.1)
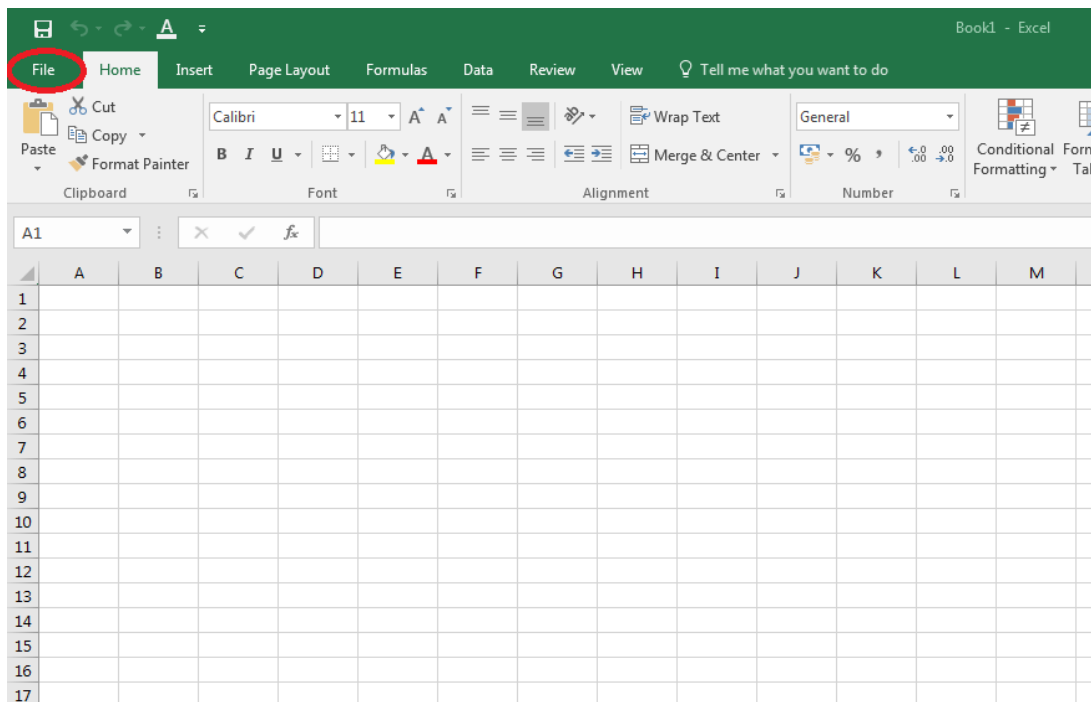

Figure 2.1: Registering FluidEXL*Graphics* as Add-In in Excel® 2016

- Click on the "Options" button in the menu which appears (see Fig. 2.2)
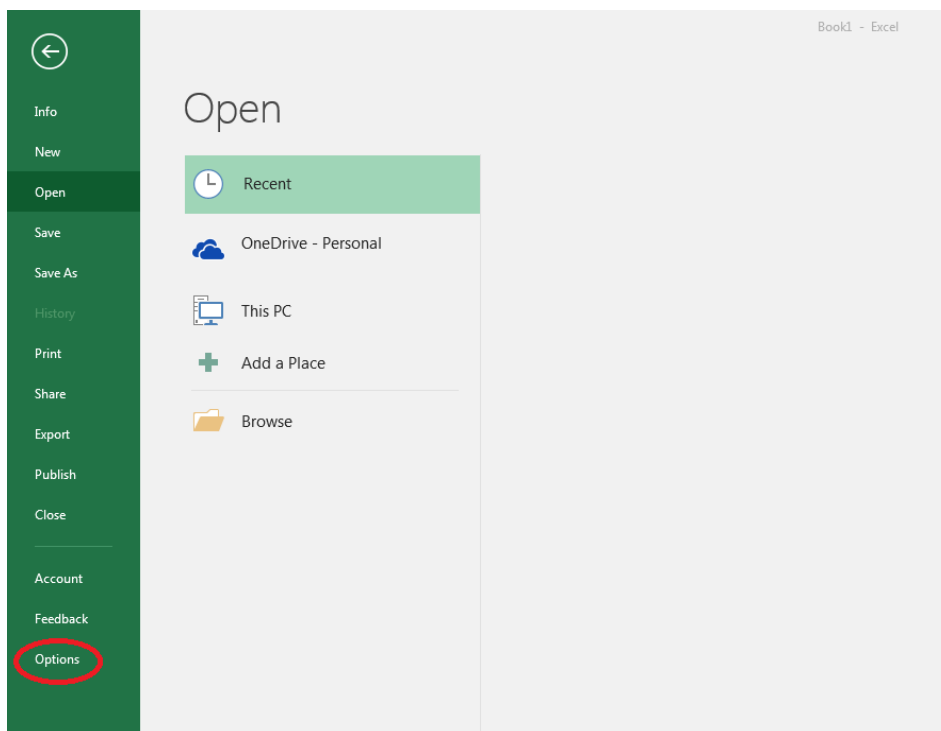

Figure 2.2: Registering FluidEXL*Graphics* as Add-In in Excel® 2016

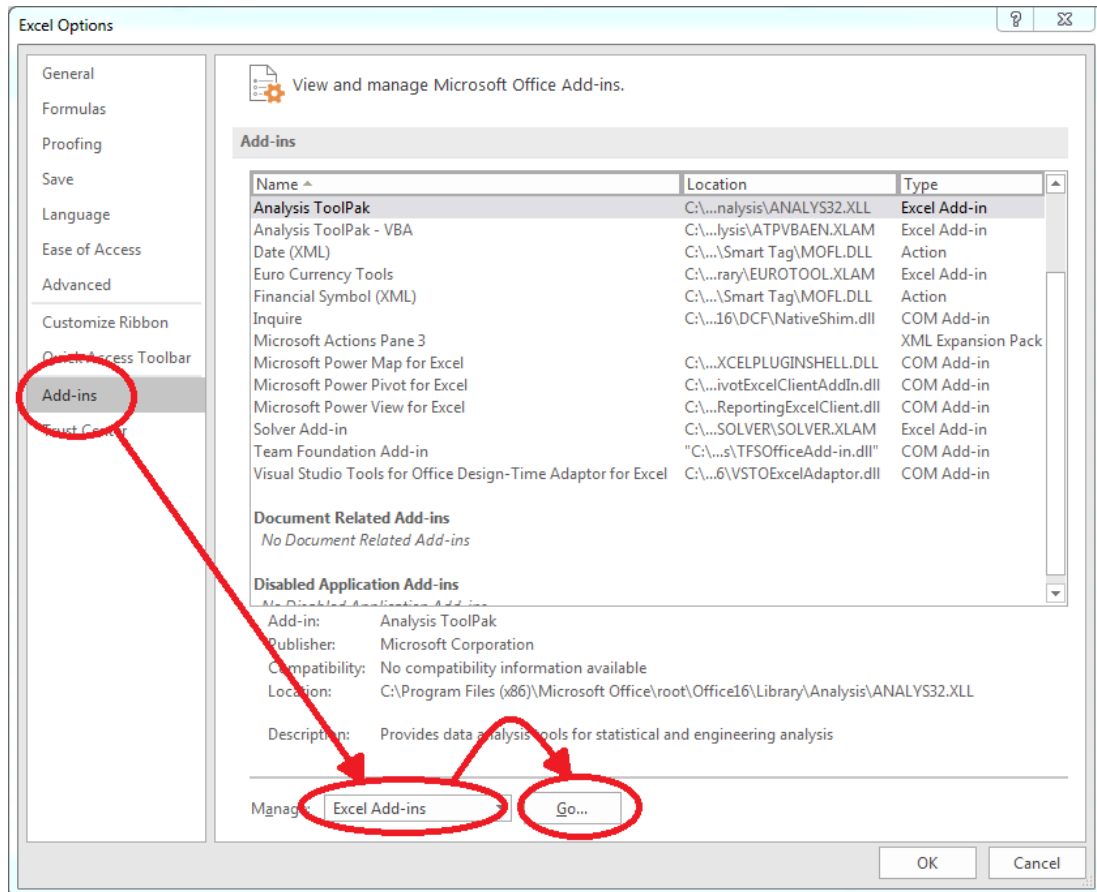- Click on "Add-Ins" in the next menu (Fig. 2.3)

Figure 2.3: Dialog window "Excel Options"

- Select "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Then click the "Go…" button
- Click "Browse" in the following window (Fig. 2.4)
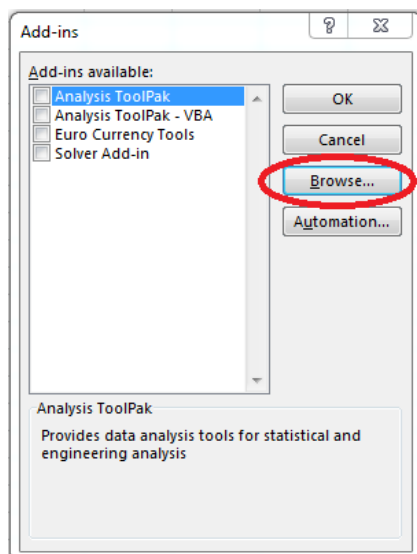

Figure 2.4: Dialog window "Add-ins"

- Excel opens the AddIns folder. This is usually

  C:\Users\[your name]\AppData\Roaming\Microsoft\AddIns\.

- If the FluidEXL files have already been copied to this directory in section 2.1, please skip the following indented section. If not, follow the indented instructions to successful paste the needed files for the FluidEXL Add-In:

  > In the upper part of the "Browse" window the correct Add-In path is displayed (see Figure 2.5). Please note that not the entire path is displayed.
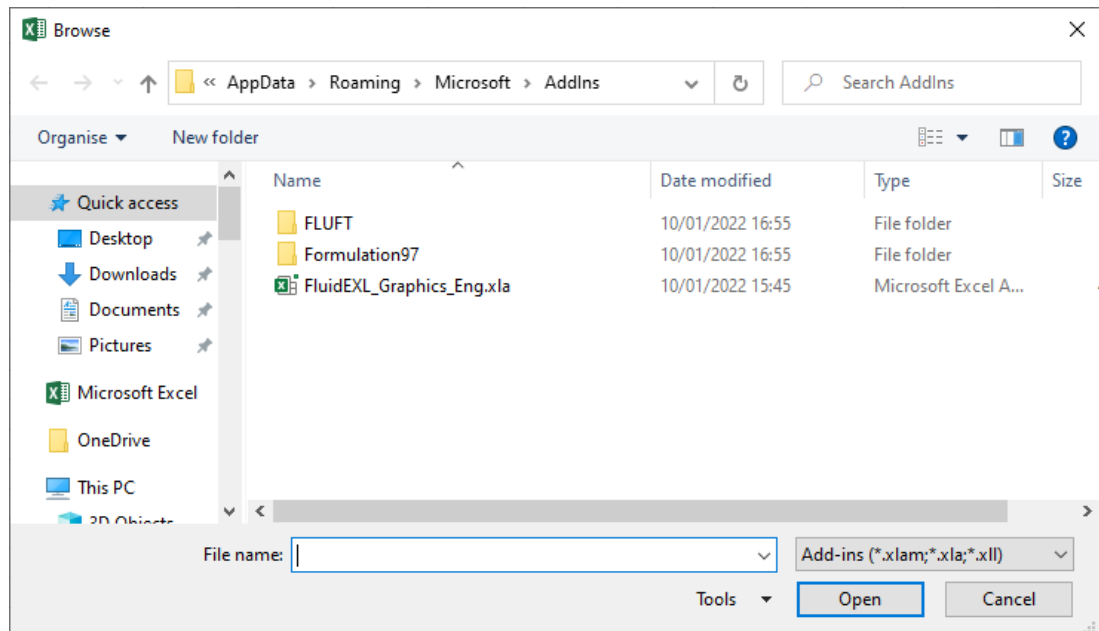

Figure 2.5: "Browse"-Window

  > Please copy this path and paste it into your file manager.
  > Now, please copy the following directories and files:
  >> \FLUFT\
  >> \Formulation97\
  >> LC.dll
  >> FluidEXL_Graphics_Eng.xla
  >> LibMD4M.dll
  >> LibMD4M.chm
  > from the delivered CD-folder into this folder.

- Click "FluidEXL_Graphics_Eng.xla" in this folder (see Fig. 2.5) and click "OK."

- Now, "FluidEXL Graphics Eng" will be shown in the list of Add-ins (see Fig. 2.6).

  (If a checkmark is in the box next to the name "FluidEXL Graphics Eng", this Add-In will automatically be loaded whenever Excel starts. This will continue to occur unless the checkmark is removed from the box by clicking on it.)

- In order to register the Add-In click the "OK" button in the "Add-ins" window (see Fig. 2.6).
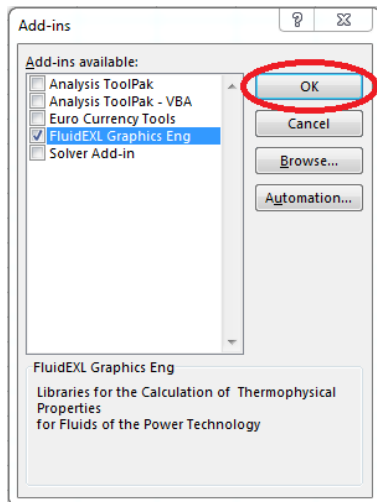
Figure 2.6: Dialog window "Add-Ins"

In order to use FluidEXL^{Graphics} in the following example, click on the menu item "Add-Ins" shown in Fig. 2.7.
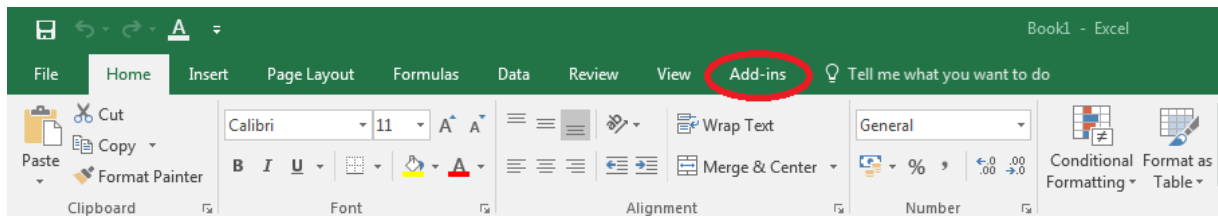
Figure 2.7: Menu item "Add-Ins"

In the upper menu region of Excel®, the FluidEXL^{Graphics} menu bar will appear as marked with the red circle in Fig. 2.8.
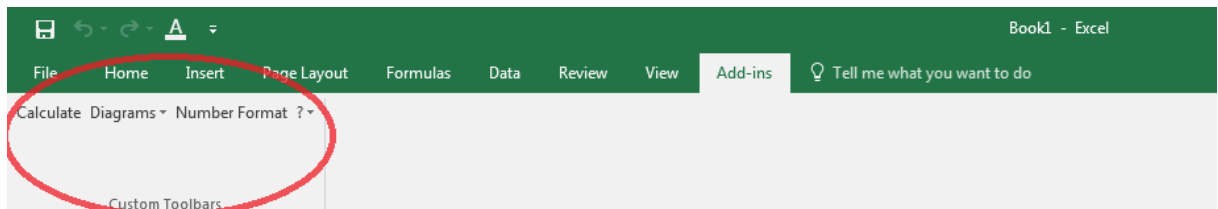
Figure 2.8: FluidEXL^{Graphics} menu bar

The Installation of FluidEXL^{Graphics} in Excel® is now complete.

An example calculation of "LibMD4M" DLL library property functions can be found in chapter 2.4.

2.3   Licensing the LibMD4M Property LibMD4Mrary

The licensing procedure has to be carried out when Excel® starts up and a FluidEXL^{Graphics} prompt message appears. In this case, you will see the "License Information" window (see figure below).

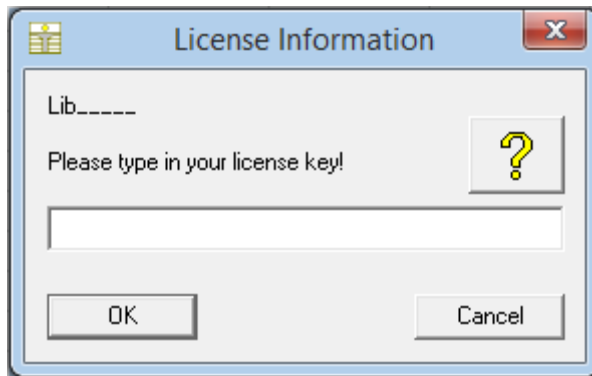**Figure 2.12:** "License Information" window

Here you will have to type in the license key. You can find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:
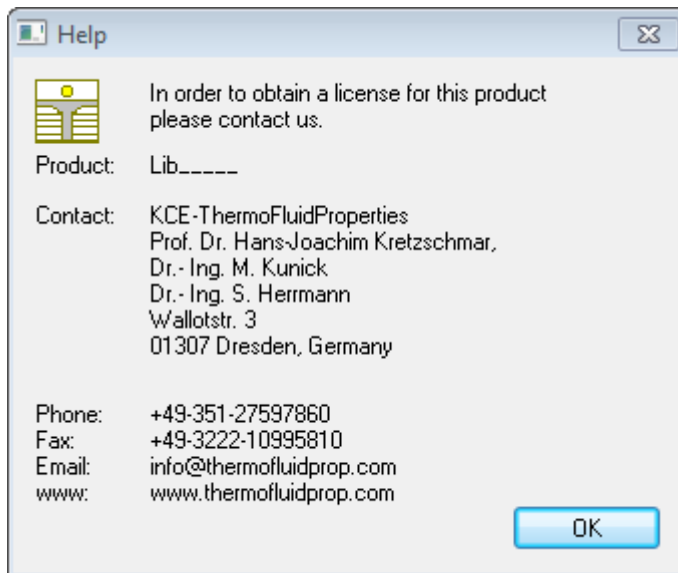
Figure 2.13: "Help" window

If you do not enter a valid license it is still possible to start Excel® by clicking "Cancel" twice. In this case, the LibMD4M property library will display the result "–11111111" for every calculation.

The "License Information" window will appear every time you start Excel® unless you uninstall FluidEXL^Graphics according to the description in section 2.6 of this User's Guide.

Should you not wish to license the LibMD4M property library, you have to delete the files

      LibMD4M.dll
      LibMD4M.chm

in the installation folder of FluidEXL^Graphics (the standard being)

   C:\Program Files\FluidEXL_Graphics_Eng

using an appropriate program such as Explorer® or Norton Commander.

Note:

The product name "LibMD4M_ _ _ _ _ in Figure 2.12 and 2.13 stands for the LibMD4Mrary you are installing. In this case it is the LibMD4M library.

2.4   Example calculation

Now we will calculate, step by step, the specific enthalpy h as a function of pressure p, temperature t, and vapor fraction x, using FluidEXL^{Graphics}. Please carry out the following steps:

- Start Excel®
- Enter a value for p in bar in a cell
  (Range of validity: $p = 0.00001$ bar to 300 bar)
  $\Rightarrow$ e. g.: Enter the value 10 into cell A2

- Enter a value for t in °C in a cell
  (Range of validity: $t = 26.85$°C to 399.85 °C)
  $\Rightarrow$ e. g.: Enter the value 300 into cell B2

- Enter a value for x in kg saturated steam/kg wet steam into a cell

  Since the wet steam region is calculated automatically by the subprograms, the following fixed details on the vapor fraction x are to be considered when the value for x is entered:

  Single-phase region

  If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

  Wet-steam region

  If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

  When calculating wet steam either the given value for t and p = -1 or the given value for p and t = -1 and in both cases the value for x between 0 and 1 must be entered.

  If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1000.

  (MD4M Saturation pressure curve:
  $$t = 26.85 \text{ °C to } t_C = 379.05 \text{ °C}$$
  $$p_S(26.85 \text{ °C}) = 0.00001093377 \text{ bar to } p_C = 8.7747391 \text{ bar})$$

  $\Rightarrow$ e.g.: Enter the value -1 into cell C2

- Click the cell in which the enthalpy h in kJ/kg is to be displayed.

  $\Rightarrow$ e.g.: Click the D2 cell

- Click "Calculate" in the menu bar of FluidEXL^{Graphics}.
  Now the "Insert Function" window appears (see next figure).
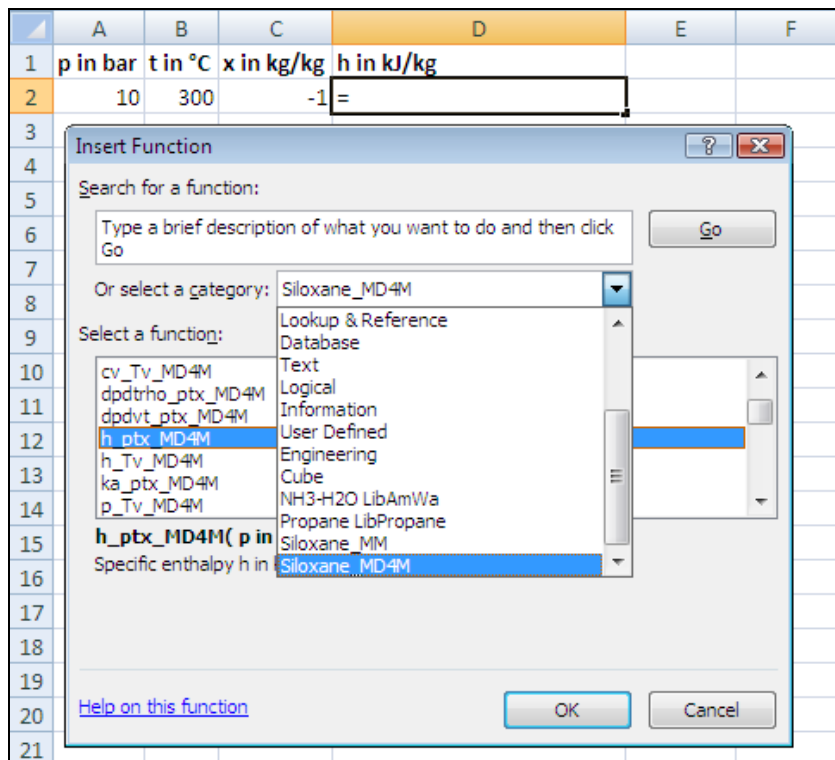
Figure 2.14: Choice of library and function name

- In the drop-down menu in the middle, next to "Or select a category:" locate and click the library "Siloxane_MD4M"
- Below this drop-down menu under "Select a function:" choose and click the function h_ptx_MD4M
  Here it is possible to get more information on the range of validity, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click the "OK" button.
  The window shown in the next figure will now appear.

Figure 2.15: Enter the given values for the property calculation

- The Cursor is now situated on the line next to "p in bar". You can now enter the value for *p* either by clicking the cell with the value for *p*, by entering the name of the cell with the value for *p*, or by entering the value for *p* directly.

    ⇒ e. g.: Click on the cell A2

- Situate the cursor next to "t in °C" and enter the value for *t* by clicking the cell with the value for *t*, by entering the name of the cell with the value for *t*, or by entering the value for *t* directly.
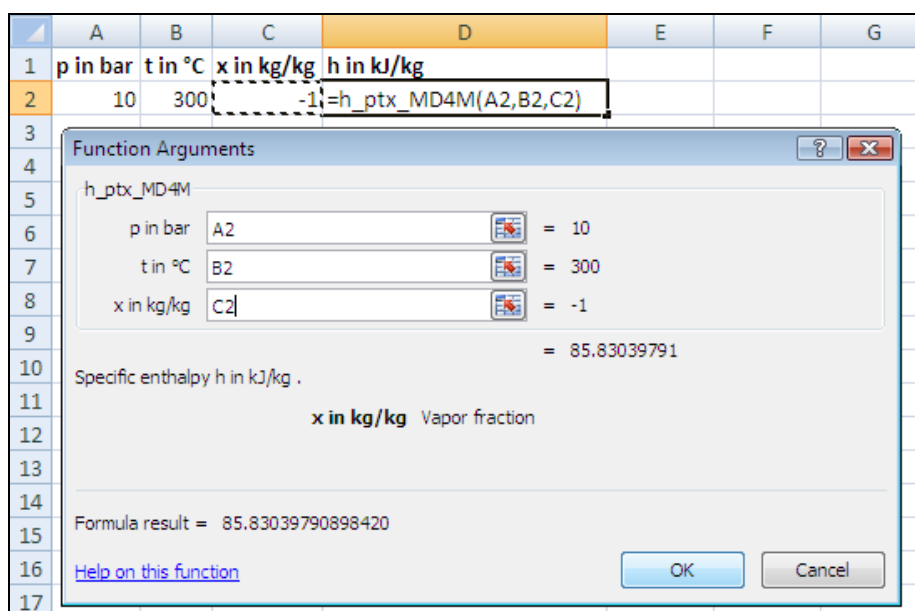
    ⇒ e. g.: Type B2 into the window next to "t in °C"

- Situate the cursor next to "x in kg/kg" and enter the value for *x* by clicking the cell with the value for *x*, by entering the name of the cell with the value for *x*, or by entering the value for *x* directly.

    ⇒ e. g.: Click on the cell C2

- Click the "OK" button.

The result for *h* in kJ/kg appears in the chosen cell.

    ⇒ The result of this example must be h = 85.83039790898420 kJ/kg

The calculation of $h = f(p,t,x)$ has been carried out. You can now arbitrarily change the values for *p*, *t*, or *x* in the appropriate cells. The specific enthalpy is recalculated and updated every time you change the data. This shows that the Excel® data flow and the DLL calculations are working together successfully.

Note.

If the calculation results in –1000, this indicates that the values entered are located outside the range of validity of LibMD4M. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL*Graphics*, see the function table in Chapter 1.

Number Formats

When using FluidEXL*Graphics* you have the option of choosing special number formats in advance.
Changes can be made as follows:

- Click the cell or select and click on the cells you wish to format.
  (In empty cells the new format will be applied once a value has been entered.)

- Click "Number Format" in the FluidEXL*Graphics* menu bar.

- Select the desired number format in the dialog box which appears:

    "STD – Standard":   Insignificant zeros behind the decimal point are not shown.

    "FIX – Fixed Number of Digits": All set decimal places are shown, including insignificant zeros.

    "SCI – Scientific Format":   Numbers are always shown in the exponential form with the set number of decimal places.

- Set the "Number of decimal places" by entering the number into the appropriate window.

- Confirm this by clicking the "OK" button.

As an example, the table below shows the three formats for the number 1.230 adjusted for three decimal places:

STD	1.23
FIX	1.230
SCI	1.230E+00

This formatting can also be applied to cells which have already been calculated.

2.5 The FluidEXL*Graphics* Help System

As mentioned earlier, FluidEXL*Graphics* also provides detailed help functions.

Information on individual property functions may be accessed via the following steps:

- Click "Calculate" in the FluidEXL*Graphics* menu bar.
- Click on the "LibMD4M" library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" button in the lower left-hand edge of the "Insert Function" window.
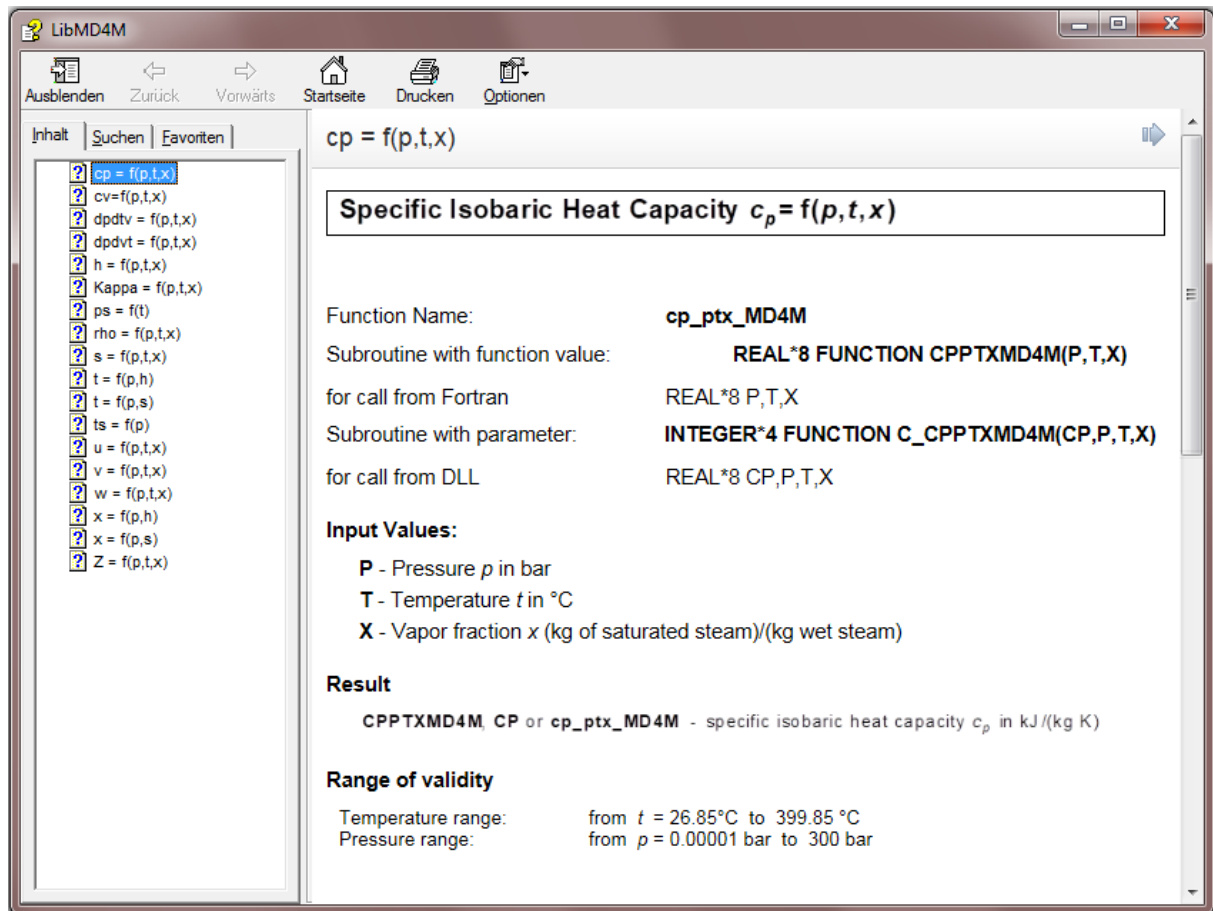

Figure 2.16: Help Window

If the LibMD4M.chm function help cannot be found, you will be redirected to a Microsoft[®] help website by your standard browser. In this case, the LibMD4M.chm file has to be copied into the folder of FluidEXL*Graphics*, in the standard case

    C:\Program Files\FluidEXL_Graphics_Eng

to use the help system.

2.6 Removing FluidEXLGraphics

2.6.1 Removing LibMD4M Library

Should you wish to remove only the LibMD4M library, delete the files

LibMD4M.dll
LibMD4M.chm

in the directory selected for the installation of FluidEXL^{Graphics}, in the standard case,

C:\Program Files\FluidEXL_Graphics_Eng

by using an appropriate program such as Explorer® or Norton Commander.

2.6.2 Unregistering and uninstalling FluidEXL^{Graphics} as Add-In in versions of Excel® from 2007 onwards (for earlier versions see 2.6.3)

In order to unregister the FluidEXL^{Graphics} Add-In in versions of Excel® from 2007 onwards start Excel® and carry out the following commands:

- Click the "File" button in the upper left corner of Excel®

- Click on the "Options" button in the menu which appears
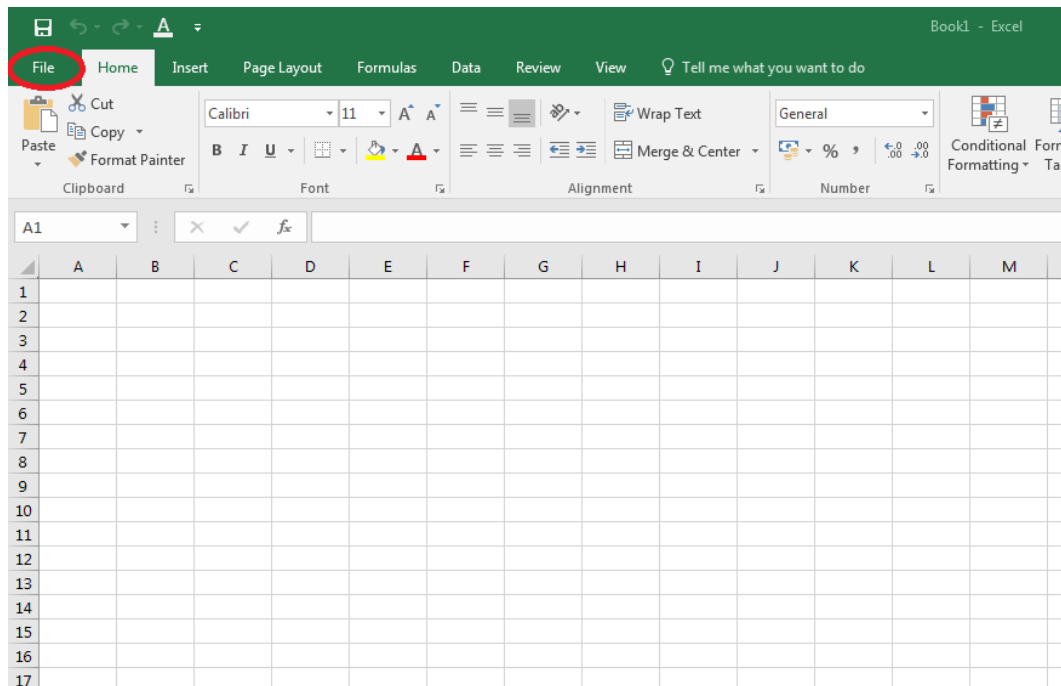

Figure 2.17: Unregistering FluidEXL^{Graphics} as Add-In in Excel® 2016
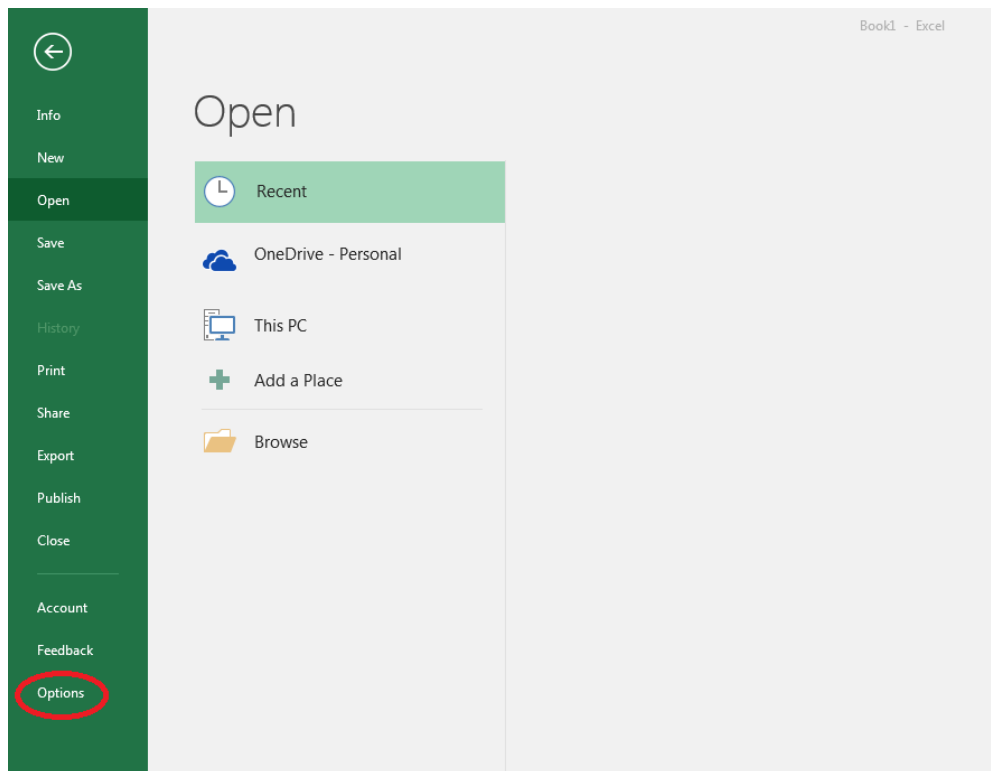
Figure 2.18 Unregistering FluidEXL^{Graphics} as Add-In in Excel® 2016

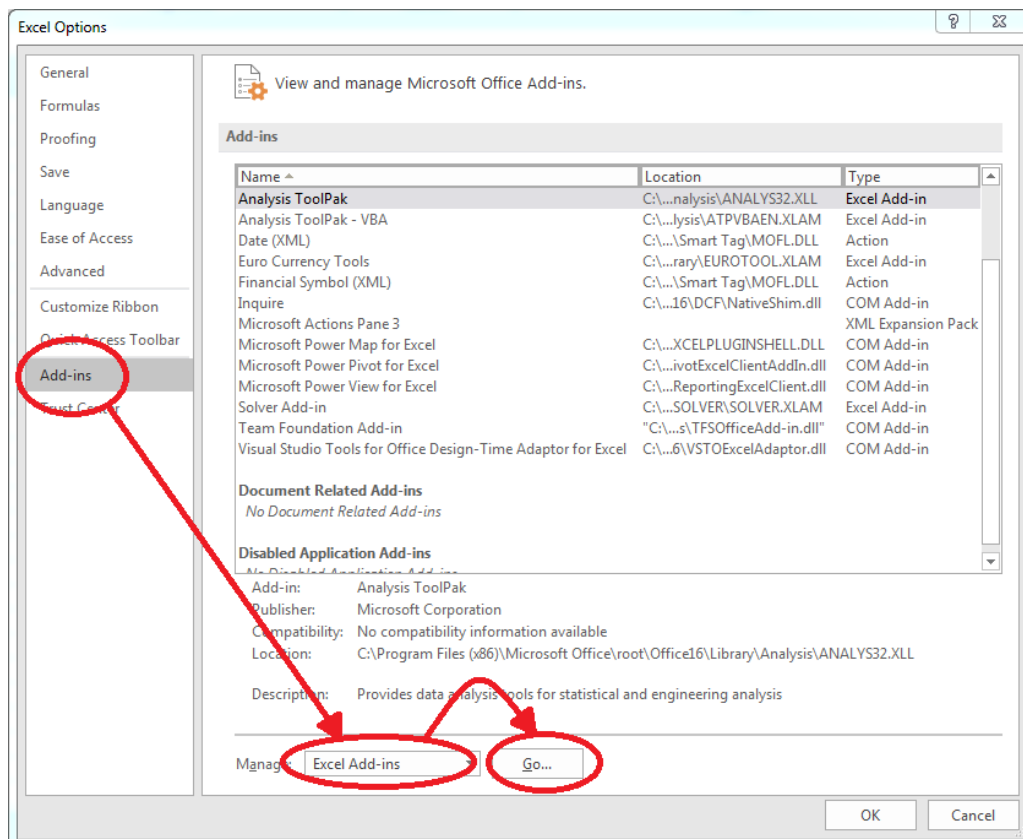- Click on "Add-Ins" in the next menu (Figure 2.19)

Figure 2.19: Dialog window "Add-Ins"

- If it is not shown in the list automatically, chose and click "Excel Add-ins" next to "Manage:" in the lower area of the menu

- Afterwards click the "Go…" button

- Remove the checkmark in front of

  "FluidEXL Graphics Eng"

 in the window which now appears. Click the "OK" button to confirm your entry.

Figure 2.20: Dialog window "Add-Ins"

In order to remove FluidEXL^{Graphics} from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel."

Now, double click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" window that appears, select

 "FluidEXL Graphics Eng"

by clicking on it and then clicking the "Add/Remove…" button.

Click "Automatic" in the following dialog box and then the "Next >" button.

Click "Finish" in the "Perform Uninstall" window.

Answer the question of whether all shared components should be removed with "Yes to All." Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidEXL^{Graphics} has been completely removed from your computer.

2.6.3 Unregistering and uninstalling FluidEXL^{Graphics} as Add-In in Excel®, versions 2003 or earlier

To remove FluidEXL^{Graphics} <u>completely,</u> proceed as follows: First the registration of

  FluidEXL_Graphics_Eng.xla

has to be cancelled in Excel®.

In order to do this, click "Tools" in the upper menu bar of Excel® and here "Add-Ins…". Untick the box on the left-hand side of

  "FluidEXL Graphics Eng"

in the window that appears and click the "OK" button. The additional menu bar of FluidEXL^{Graphics} disappears from the upper part of the Excel® window. Afterwards, we

recommend closing Excel®.

If the FluidEXL*Graphics* menu bar does not disappear, take the following steps:
Click "View" in the upper menu bar of Excel®, then "Toolbars" and then "Customize…" in the list box which appears.

"FluidEXL Graphics Eng"

is situated at the bottom of the "Toolbars" entries, which must be selected by clicking on it. Delete the entry by clicking "Delete". You will be asked whether you really want to delete the toolbar – click "OK".

Within the next step delete the files

LibMD4M.dll
LibMD4M.chm

in the directory selected for the installation of FluidEXL*Graphics*, in the standard case,

C:\Program Files\FluidEXL_Graphics_Eng

using an appropriate program such as Explorer® or Norton Commander.
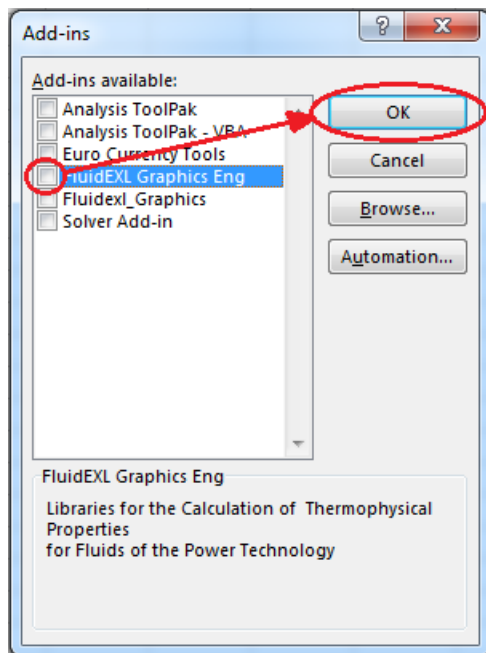
In order to remove FluidEXL*Graphics* from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel". Now double-click on "Add or Remove Programs". In the list box of the "Add/Remove Programs" window that appears select

"FluidEXL Graphics Eng"

by clicking on it and click the "Add/Remove…" button. In the following dialog box, click "Automatic" and then "Next >". Click "Finish" in the "Perform Uninstall" window. Answer the question whether all shared components shall be removed with "Yes to All". Finally, close the "Add/Remove Programs" and "Control Panel" windows.

Now FluidEXL*Graphics* has been removed.

3.   Program Documentation

Specific Isobaric Heat Capacity $c_p = f(p, t, x)$

Function Name: **cp_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION CPPTXMD4M(P,T,X)**
for call from Fortran   REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

CPPTXMD4M, **CP** or **cp_ptx_MD4M** - specific isobaric heat capacity c_p in kJ/(kg K)

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and   Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

saturated vapor line: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **CPPTXMD4M = -1000**, **CP = -1000** or **cp_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(x = -1) $t > 399.85$ °C or $t < 26.85$°C

Saturation lines: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C
                              at $t = -1000$ and $p > p_c = 8.7747391$ bar
                                 or $p < p_s(26.85°C) = 0.00001093377$ bar or
                              at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
                                 $t > t_c = 379.05$ °C or $t < 26.85$ °C

References: [1]

Specific Isochoric Heat Capacity $c_v = f(p, t, x)$

Function Name:	**cv_ptx_MD4M**
Subroutine with function value:	**REAL*8 FUNCTION CVPTXMD4M(P,T,X)**
for call from Fortran	REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

 CVPTXMD4M, **CV** or **cv _ptx _MD4M** - specific isochoric heat capacity c_v in kJ/(kg K)

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x (x = 0 or x = 1). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and   Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

saturated vapor line: Pr essure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **CVPTXMD4M = -1000**, **CV = -1000** or **cv_ptx_MD4M = -1000** for input values:

Single phase region: ($x = -1$)	$p > 300$ bar or $p < 0.00001$ bar or $t > 399.85$ °C or $t < 26.85$°C

Saturation lines:	at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C
	at $t = -1000$ and $p > p_c = 8.7747391$ bar
	   or $p < p_s(26.85°C) = 0.00001093377$ bar or
	at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
	   $t > t_c = 379.05$ °C or $t < 26.85$°C

References: [1]

Derivative of Pressure with Respect to Temperature (at Constant Specific Volume) $\left(\dfrac{\partial p}{\partial T}\right)_v = f(p, t, x)$

Function Name: **dpdtv_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION DPDTVPTXMD4M(P,T,X)**
for call from Fortran   REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

DPDTVPTXMD4M, **DPDTV** or **dpdtv_ptx_MD4M** -   Derivative of pressure with respect to temperature (at constant specific volume) dpdtv in kPa/K

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x ($x = 0$ or $x = 1$). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and   Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

saturated vapor line: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **DPDTVPTXMD4M = -1000**, **DPDTV = -1000** or **dpdtvo_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
($x = -1$) $t > 399.85$ °C or $t < 26.85°C$

Saturation lines: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C
    at $t = -1000$ and $p > p_c = 8.7747391$ bar
      or $p < p_s(26.85°C) = 0.00001093377$ bar or
    at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
      $t > t_c = 379.05$ °C or $t < 26.85°C$

References: [1]

Derivative of Pressure with Respect to Specific Volume (at Constant Temperature) $\left(\dfrac{\partial p}{\partial v}\right)_T = f(p, t, x)$

Function Name: **dpdvt_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION DPDVTPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

DPDVTPTXMD4M, **DPDVT** or **dpdvt_ptx_MD4M** - Derivative of pressure with respect to temperature (at constant specific volume) dpdvt in kPa/K

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction *x* and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
The calculation for *x*-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* (x = 0 or x = 1). If *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the vapor pressure curve.

Saturated liquid and Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

saturated vapor line: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **DPDVTPTXMD4M = -1000**, **DPDVT = -1000** or **dpdvt_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(*x* = -1) $t > 399.85$ °C or $t < 26.85°C$

Saturation lines: at p = -1000 and $t > t_c = 379.05$ °C or $t < 26.85$ °C
at t = -1000 and $p > p_c = 8.7747391$ bar
or $p < p_s(26.85°C) = 0.00001093377$ bar or
at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
$t > t_c = 379.05$ °C or $t < 26.85°C$

References: [1]

Dynamic Viscosity η = f(p,t,x)

Function Name:	**eta_ptx_MD4M**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION ETAPTXMD4M(P,T,X)** REAL*8 P,T,X

Input Values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

ETAPTXMD4M, **ETA** or **eta_ptx_MD4M –** Dynamic viscosity η in Pa·s

Range of validity

Temperature range:	from t = 26.85°C to 399.85 °C
Pressure range:	from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = −1 must be entered as a pro-forma value. Here the backward functions will also result in x = −1.

Wet-steam region

When calculating wet steam, a value between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for x. It is adequate to enter either the given value for t <u>and</u> p = −1, or the given value for p <u>and</u> t = −1, plus the value for x between 0 and 1. When p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in −1.

Wet steam region:	Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
	Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **ETAPTXMD4M = -1000**, **ETA = -1000** or **eta_ptx_MD4M = -1000** for Input Values

Single phase region: (x = -1)	$p > 300$ bar or $p < 0.00001$ bar or $t > 399.85$ °C or $t < 26.85°C$
Wet steam region:	at p = -1000 and $t > t_c = 379.05$ °C or $t < 26.85$ °C
	at t = -1000 and $p > p_c = 8.7747391$ bar
	or $p < p_s(26.85°C) = 0.00001093377$ bar or
	at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
	$t > t_c = 379.05$ °C or $t < 26.85°C$

References: [2],[3], internal calculation from ρ or v [1]

Specific Enthalpy h = f(p,t,x)

Function Name: **h_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION HPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

HPTXMD4M, **H** or **h_ptx_MD4M** - specific enthalpy h in kJ/kg

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t <u>and</u> p = -1000 or the given value for p <u>and</u> t = -1000 and in both cases the value for x between 0 and 1 must be entered.

If p <u>and</u> t <u>and</u> x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **HPTXMD4M = -1000**, **H = -1000** or **h_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
($x = -1$) $t > 399.85$ °C or $t < 26.85°C$

Wet steam region: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C

at $t = -1000$ and $p > p_c = 8.7747391$ bar

or $p < p_s(26.85°C) = 0.00001093377$ bar or

at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and

$t > t_c = 379.05$ °C or $t < 26.85°C$

References: [1]

Isentropic Exponent $\kappa = \text{f}(p,t,x)$

Function Name:	**kappa_ptx_MD4M**
Subroutine with function value:	**REAL*8 FUNCTION KAPPAPTXMD4M(P,T,X)**
for call from Fortran	REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

KAPPAPTXMD4M, **KAPPA** or **kappa_ptx_MD4M** - Isentropic exponent $\kappa = \dfrac{w^2}{p \cdot v}$

Range of validity

Temperature range: from $t = 26.85°C$ to $399.85\ °C$

Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located on the saturated liquid line, $x = 0$ must be entered. When calculating saturated steam (saturated vapor line) $x = 1$ must be entered.
The calculation for x-values between 0 and 1 is not possible.

When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t <u>and</u> p = -1000, or the given value for p <u>and</u> t = -1000, plus the value for x ($x = 0$ or $x = 1$). If p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and	Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
saturated vapor line:	Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **KAPPAPTXMD4M**, **KAPPA = -1000** or **kappa_ptx_MD4M = -1000** for input values:

Single phase region:	$p > 300$ bar or $p < 0.00001$ bar or
($x = -1$)	$t > 399.85\ °C$ or $t < 26.85°C$

Saturation lines:	at $p = -1000$ and $t > t_c = 379.05\ °C$ or $t < 26.85\ °C$
	at $t = -1000$ and $p > p_c = 8.7747391$ bar
	or $p < p_s(26.85°C) = 0.00001093377$ bar or
	at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
	$t > t_c = 379.05\ °C$ or $t < 26.85°C$

References: [1]

Thermal Conductivity λ = f(p,t,x)

Function Name: **lambda_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION LAMPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

LAMPTXMD4M, **LAM** or **lambda_ptx_MD4M –** Thermal conductivity λ in W/(m·K)

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

Single-phase region

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value. Here the backward functions will also result in x = –1.

Wet-steam region

When calculating wet steam, a value between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for x. It is adequate to enter either the given value for t and p = –1, or the given value for p and t = –1, plus the value for x between 0 and 1. When p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1.

Saturated liquid and saturated vapor line: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **LAMPTXMD4M = -1000**, **LAM = -1000** or **lambda_ptx_MD4M = -1000** for Input Values

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(x = -1) $t > 399.85$ °C or $t < 26.85$°C

Saturation lines: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C

at $t = -1000$ and $p > p_c = 8.7747391$ bar

or $p < p_s(26.85°C) = 0.00001093377$ bar or

at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and

$t > t_c = 379.05$ °C or $t < 26.85$°C

References: [2], [3], [4], internal calculation from ρ or v [1]

Kinematic Viscosity $\nu = f(p,t,x)$

Function Name: **nu_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION NUPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values

   P - Pressure p in bar

   T - Temperature t in °C

   X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

   NUPTXD4, **NU** or **nu_ptx_D4** - Kinematic viscosity $\nu = \dfrac{\eta}{\rho} = \eta \cdot v$ in m^2/s

Range of validity

   Temperature range: from $t = 26.85$°C to 399.85 °C
   Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

   Single-phase region

   If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value. Here the backward functions will also result in x = –1.

   Wet-steam region

   When calculating wet steam, a value between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered. In this case, the backward functions result in the appropriate value between 0 and 1 for x. It is adequate to enter either the given value for t <u>and</u> p = –1, or the given value for p <u>and</u> t = –1, plus the value for x between 0 and 1. When p <u>and</u> t <u>and</u> x are entered as given values, the program will consider p and t to be appropriate to represent the saturation-pressure curve. If it is not the case the calculation for the property of the chosen function to be calculated results in –1.

Saturated liquid and   Temperature ranges from $t = 26.85$°C to $t_c = 379.05$°C

saturated vapor line: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **NUPTXMD4M = -1000**, **NU = -1000** or **nu_ptx_MD4M = -1000** for Input Values

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(x = -1) $t > 399.85$ °C or $t < 26.85$°C

Saturation lines: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C
             at $t = -1000$ and $p > p_c = 8.7747391$ bar
               or $p < p_s(26.85°C) = 0.00001093377$ bar or
             at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
               $t > t_c = 379.05$ °C or $t < 26.85$ °C

References: Internal calculation from ρ or v [1] and η [2], [3]

Vapor Pressure $p_s = f(t)$

Function Name: **ps_t_MD4M**

Subroutine with function value: **REAL*8 FUNCTION PSTMD4M(T)**
for call from Fortran   REAL*8 T

Input Values:

T - Temperature t in °C

Result

PSTMD4M, **PS** or **ps_t_MD4M** - Vapor pressure p_s in bar

Range of validity

Temperature range :   from $t = 26.85°C$ to $t_c = 379.05$ °C

Results for wrong input values

Result **PSTMD4M = -1000**, **PS = -1000** or **ps_t_MD4M = -1000** for input values:

$t < 26.85°C$ or $t > t_c = 379.05$ °C

References: [1]

Density $\rho = f(p, t, x)$

Function Name:	**rho_ptx_MD4M**
Subroutine with function value:	**REAL*8 FUNCTION RHOPTXMD4M(P,T,X)**
for call from Fortran	REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

RHO_PTX_MD4M, **RHO** or **rho_ptx_MD4M** - Density ρ in kg/m^3

Range of validity

Temperature range: from $t = 26.85°C$ to $399.85 °C$
Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the vapor fraction *x* and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for *x* between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for t <u>and</u> p = -1000 or the given value for p <u>and</u> t = -1000 and in both cases the value for *x* between 0 and 1 must be entered.

If p <u>and</u> t <u>and</u> x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

Wet steam region: Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$

Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **RHOPTXMD4M = -1000**, **RHO = -1000** or **rho_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(x = -1) $t > 399.85 °C$ or $t < 26.85°C$

Wet steam region: at $p = -1000$ and $t > t_c = 379.05 °C$ or $t < 26.85 °C$

at $t = -1000$ and $p > p_c = 8.7747391$ bar

or $p < p_s(26.85°C) = 0.00001093377$ bar or

at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and

$t > t_c = 379.05 °C$ or $t < 26.85°C$

References: [1]

Specific Entropy $s = f(p,t,x)$

Function Name: **s_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION SPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

SPTXMD4M, **S** or **s_ptx_MD4M** - Specific entropy s in kJ/kg K

Range of validity

Temperature range: from $t = 26.85$°C to 399.85 °C
Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 ($x = 0$ for saturated liquid, $x = 1$ for saturated steam) must be entered.

When calculating wet steam either the given value for t <u>and</u> p = -1000 or the given value for p <u>and</u> t = -1000 and in both cases the value for x between 0 and 1 must be entered.

If p <u>and</u> t <u>and</u> x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

Wet steam region: Temperature ranges from $t = 26.85$°C to $t_c = 379.05$°C

Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **SPTXMD4M = -1000**, **S = -1000** or **s_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
($x = -1$) $t > 399.85$ °C or $t < 26.85$°C

Wet steam region: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C

at $t = -1000$ and $p > p_c = 8.7747391$ bar

or $p < p_s(26.85°C) = 0.00001093377$ bar or

at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and

$t > t_c = 379.05$ °C or $t < 26.85$ °C

References: [1]

Backward Function: Temperature $t = f(p,h)$

Function Name: **t_ph_MD4M**

Subroutine with function value: **REAL*8 FUNCTION TPHMD4M(P,H)**
for call from Fortran   REAL*8 P,H

Input Values:

    P - Pressure p in bar

    H - Specific enthalpy h in kJ/kg

Result

    TPHMD4M, **T** or **t_ph_MD4M -** Temperature t in °C

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pr essure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **T_PH_MD4M**, **T = -1000** or **t_ph_MD4M = -1000** for input values:

Single phase region: at $p >$ 300 bar or $p < p_s(26.85°C) = 0.00001093377$ bar or
(x = -1)   at result $t >$ 399.85 °C, $t <$ 26.85°C

Boiling or dew curve: at $p > p_c = 8.7747391$ bar or $p < p_s$ 26.85°C = 0.00001093377 bar
                           at result $t > t_c = 379.05$ °C or $t <$ 26.85 °C

References: [1]

Backward Function: Temperature t = f(p,s)

Function Name: **t_ps_MD4M**

Subroutine with function value: **REAL*8 FUNCTION TPSMD4M(P,S)**
for call from Fortran   REAL*8 P,S

Input Values:

P - Pressure p in bar

S - Specific entropy s in kJ/(kg K)

Result

TPSMD4M, **T** or **t_ps_MD4M -** Temperature t in °C

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. Afterwards the calculation of t in the appropriate region will be carried out.

Wet steam region: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **T_PS_MD4M**, **T = -1000** or **t_ps_MD4M = -1000** for input values:

Single phase region: at p > 300 bar or $p < p_s(26.85°C) = 0.00001093377$ bar or

(x = -1)   at result t > 399.85 °C, t < 26.85°C

Boiling or dew curve: at $p > p_c = 8.7747391$ bar or $p < p_s$ 26.85°C = 0.00001093377

at result $t > t_c = 379.05$ °C or t < 26.85 °C

References: [1]

Saturation Temperature t_s = f(p)

Function Name: **ts_p_MD4M**

Subroutine with function value: **REAL*8 FUNCTION TSPMD4M(P)**
for call from Fortran   REAL*8 P

Input Values:

     P - Pressure p in bar

Result

     TSPMD4M, **TS** or **ts_p_MD4M** - Saturation temperature t_s in °C

Range of validity

Pressure range :   from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **TSPMD4M = -1000**, **TS = -1000** or **ts_p_MD4M = -1000** for input values:

     $p < p_s(26.85°C) = 0.00001093377$ bar or $p > p_c = 8.7747391$ bar

References: [1]

Specific Internal Energy $u = f(p,t,x)$

Function Name: **u_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION UPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values:

    P - Pressure p in bar

    T - Temperature t in °C

    X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

    UPTXMD4M, **U** or **u_ptx_MD4M** - Specific internal energy u in kJ/kg

Range of validity

Temperature range: from t = 26.85°C to 399.85 °C
Pressure range: from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

    If the state point to be calculated is located in the single-phase region (liquid or superheated steam) $x = -1$ must be entered as a pro-forma value.

    If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

    When calculating wet steam either the given value for t <u>and</u> p = -1000 or the given value for p <u>and</u> t = -1000 and in both cases the value for x between 0 and 1 must be entered.

    If p <u>and</u> t <u>and</u> x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

Wet steam region: Temperature ranges from t = 26.85°C to t_c = 379.05°C

                      Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **UPTXMD4M = -1000**, **U = -1000** or **u_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(x = -1) $t > 399.85$ °C or $t < 26.85$°C

Wet steam region: at p = -1000 and $t > t_c$ = 379.05 °C or $t < 26.85$ °C

                      at t = -1000 and $p > p_c$ = 8.7747391 bar

                        or $p < p_s(26.85°C) = 0.00001093377$ bar or

                      at $p > p_c$ = 8.7747391 bar or $p < p_s(26.85°C) = 0.00001093377$ bar and

                        $t > t_c$ = 379.05 °C or $t < 26.85°C$

References: [1]

Specific Volume $v = f(p,t,x)$

Function Name: **v_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION VPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values:

P - Pressure p in bar

T - Temperature t in °C

X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

VPTXMD4M, **V** or **v_ptx_MD4M** - Specific volume v in m^3/kg

Range of validity

Temperature range: from $t = 26.85$°C to 399.85 °C
Pressure range: from $p = 0.00001$ bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

If the state point to be calculated is located in the wet steam region, a value for x between 0 and 1 (x = 0 for saturated liquid, x = 1 for saturated steam) must be entered.

When calculating wet steam either the given value for t and p = -1000 or the given value for p and t = -1000 and in both cases the value for x between 0 and 1 must be entered.

If p and t and x are entered as given values, the program considers p and t to be appropriate to represent the vapor pressure curve.

Wet steam region: Temperature ranges from $t = 26.85$°C to $t_c = 379.05$°C

Pressure ranges from $p_s(26.85$°C$) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **VPTXMD4M = -1000**, **V = -1000** or **v_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(x = -1) $t > 399.85$ °C or $t < 26.85$°C

Wet steam region: at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C

at $t = -1000$ and $p > p_c = 8.7747391$ bar

or $p < p_s(26.85$°C$) = 0.00001093377$ bar or

at $p > p_c = 8.7747391$ bar or $p < p_s(26.85$°C$) = 0.00001093377$ bar and

$t > t_c = 379.05$ °C or $t < 26.85$°C

References: [1]

Isentropic Speed of Sound $w = f(p,t,x)$

Function Name:	**w_ptx_MD4M**
Subroutine with function value: for call from Fortran	**REAL*8 FUNCTION WPTXMD4M(P,T,X)** REAL*8 P,T,X

Input Values:

  P - Pressure p in bar

  T - Temperature t in °C

  X - Vapor fraction x (kg of saturated steam)/(kg wet steam)

Result

  WPTXMD4M, **W** or **w_ptx_MD4M -** Speed of sound w in m/s

Range of validity

Temperature range:	from t = 26.85°C to 399.85 °C
Pressure range:	from p = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of saturated liquid and saturated steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction x are to be considered:

  If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = –1 must be entered as a pro-forma value.

  If the state point to be calculated is located on the saturated liquid line, x = 0 must be entered. When calculating saturated steam (saturated vapor line) x = 1 must be entered.
  The calculation for x-values between 0 and 1 is not possible.

  When calculating saturated liquid or saturated steam, it is adequate to enter either the given value for t and p = -1000, or the given value for p and t = -1000, plus the value for x (x = 0 or x = 1). If p and t and x are entered as given values, the program will consider p and t to be appropriate to represent the vapor pressure curve.

Saturated liquid and	Temperature ranges from $t = 26.85°C$ to $t_c = 379.05°C$
saturated vapor line:	Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **WPTXMD4M = -1000, W = -1000** or **w_ptx_MD4M = -1000** for input values:

Single phase region: (x = -1)	$p > 300$ bar or $p < 0.00001$ bar or $t > 399.85$ °C or $t < 26.85°C$

Boiling or dew curve:	at $p = -1000$ and $t > t_c = 379.05$ °C or $t < 26.85$ °C
	at $t = -1000$ and $p > p_c = 8.7747391$ bar
	  or $p < p_s(26.85°C) = 0.00001093377$ bar or
	at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and
	  $t > t_c = 379.05$ °C or $t < 26.85°C$

References: [1]

Backward Function: Vapor fraction x = f(p,h)

Function Name: **x_ph_MD4M**

Subroutine with function value: **REAL*8 FUNCTION XPHMD4M(P,H)**
for call from Fortran REAL*8 P,H

Input Values:

P - Pressure p in bar

H - Specific enthalpy h in kJ/kg

Result

XPHMD4M, **X** or **x_ph_MD4M -** Vapor fraction x in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from $t = 26.85°C$ to $t_c = 380.05 °C$

Pressure range: from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and h the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result x = - 1 will be returned.

Wet steam region: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **X_PH_MD4M**, **X =** -1 or **x_ph_MD4M =** -1 for input values:

If the state point is located in the single phase region:
$p > p_c = 8.7747391$ bar or $p < 0.00001093377$ bar

References: [1]

Backward Function: Vapor Fraction $x = f(p,s)$

Function Name: **x_ps_MD4M**

Subroutine with function value: **REAL*8 FUNCTION XPSMD4M(P,S)**
for call from Fortran REAL*8 P,S

Input Values:

P - Pressure p in bar

S - Specific entropy s in kJ/(kg K)

Result

XPSMD4M, **X** or **x_ps_MD4M** - Vapor fraction x in (kg saturated steam/kg wet steam)

Range of validity

Temperature range: from $t = 26.85°C$ to $t_c = 380.05\ °C$

Pressure range: from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Details on the calculation of wet steam

The wet steam region is calculated automatically. This means that from the given values of p and s the function will determine whether the state point to be calculated is located within the single-phase region (liquid or steam) or the wet steam region. When calculating wet steam the value for x between 0 and 1 is calculated (0 for saturated liquid, 1 for saturated steam). If the state point to be calculated is located in the single-phase region the result x = - 1 will be returned.

Wet steam region: Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **X_PS_MD4M**, **X = -1** or **x_ps_MD4M = -1** for input values:

If the state point is located in the single phase region:
$p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar

References: [1]

Compression Factor *Z* = f(*p*,*t*,*x*)

Function Name: **Z_ptx_MD4M**

Subroutine with function value: **REAL*8 FUNCTION ZPTXMD4M(P,T,X)**
for call from Fortran REAL*8 P,T,X

Input Values:

P - Pressure *p* in bar

T - Temperature *t* in °C

X - Vapor fraction *x* (kg of saturated steam)/(kg wet steam)

Result

ZPTXMD4M, **Z** or **Z_ptx_MD4M -** Compression Factor

Range of validity

Temperature range: from *t* = 26.85°C to 399.85 °C
Pressure range: from *p* = 0.00001 bar to 300 bar

Details on the vapor fraction x and on the calculation of wet steam

The wet steam region is calculated automatically by the subprograms. For this purpose the following fixed details on the vapor fraction *x* are to be considered:

If the state point to be calculated is located in the single-phase region (liquid or superheated steam) x = -1 must be entered as a pro-forma value.

If the state point to be calculated is located on the boiling curve, x = 0 must be entered. When calculating saturated steam (dew curve) x = 1 is entered as given value. The calculation for *x* values between 0 and 1 is not possible.

If the state point to be calculated is located in the two phase region, it is adequate to enter either the given value for *t* <u>and</u> p = -1000, or the given value for *p* <u>and</u> t = -1000, plus the value for *x* between 0 and 1. When calculating wet steam and *p* <u>and</u> *t* <u>and</u> *x* are entered as given values, the program will consider *p* and *t* to be appropriate to represent the saturation-pressure curve.

Boiling and dew curve: Temperature ranges from $t = 26.85°C$ to $t_c = 380.05°C$

Pressure ranges from $p_s(26.85°C) = 0.00001093377$ bar to $p_c = 8.7747391$ bar

Results for wrong input values

Result **ZPTXMD4M = -1000, Z = -1000** or **Z_ptx_MD4M = -1000** for input values:

Single phase region: $p > 300$ bar or $p < 0.00001$ bar or
(*x* = -1) $t > 399.85$ °C or $t < 26.85°C$

Boiling or dew curve: at $p = -1000$ and $t > t_c = 380.05$ °C or $t < 26.85$ °C

at $t = -1000$ and $p > p_c = 8.7747391$ bar

   or $p < p_s(26.85°C) = 0.00001093377$ bar or

at $p > p_c = 8.7747391$ bar or $p < p_s(26.85°C) = 0.00001093377$ bar and

   $t > t_c = 380.05$ °C or $t < 26.85°C$

References: [1]

KCE-ThermoFluidProperties
www.thermofluidprop.com

KCE ThermoFluidProperties

Hochschule Zittau/Görlitz — UNIVERSITY OF APPLIED SCIENCES

Property Libraries for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Water and Steam

Library LibIF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards IAPWS-IF97-S01, -S03rev, -S04, and -S05
- IAPWS Revised Advisory Note No. 3 on Thermo-dynamic Derivatives (2008)

Library LibIF97_META

- Industrial Formulation IAPWS-IF97 (Revision 2007) for metastable steam

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:

CO_2 - Span, Wagner H_2O - IAPWS-95
O_2 - Schmidt, Wagner N_2 - Span et al.
Ar - Tegeler et al.

and of the ideal gases:

SO_2, CO, Ne
(Scientific Formulation of Bücker et al.)

Consideration of:
- Dissociation from VDI 4670
- Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:

- Dry air from Lemmon et al.
- Steam, water and ice from IAPWS-IF97 and IAPWS-06

Consideration of:
- Condensation and freezing of steam
- Dissociation from VDI 4670
- Poynting effect from ASHRAE RP-1485

Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

Library LibSBTL_IF97
Library LibSBTL_95
Library LibSBTL_HuAir

For steam, water, humid air, carbon dioxide and other fluids and mixtures according IAPWS Guideline 2015 for Computational Fluid Dynamics (CFD), real-time and non-stationary simulations

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:

Ar	NO	He	Propylene
Ne	H_2O	F_2	Propane
N_2	SO_2	NH_3	Iso-Butane
O_2	H_2	Methane	n-Butane
CO	H_2S	Ethane	Benzene
CO_2	OH	Ethylene	Methanol
Air			

Consideration of:
- Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:
- Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

Model: Virial equation from ASHRAE Report RP-1485 for real mixture of the real fluids:
- Dry air
- Steam

Consideration of:
- Enhancement of the partial saturation pressure of water vapor at elevated total pressures

www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia
Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a
Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane
Library LibButane_Iso

Formulation of Bücker and Wagner (2006)

n-Butane
Library LibButane_n

Formulation of Bücker and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures
Library LibAmWa

IAPWS Guideline 2001 of Tillner-Roth and Friend (1998)

Helmholtz energy equation for the mixing term

(also useable for calculating the Kalina Cycle)

Water/Lithium Bromide Mixtures
Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)

Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants
Library LibSecRef

Liquid solutions of water with

$C_2H_6O_2$	Ethylene glycol
$C_3H_8O_2$	Propylene glycol
C_2H_5OH	Ethanol
CH_3OH	Methanol
$C_3H_8O_3$	Glycerol
K_2CO_3	Potassium carbonate
$CaCl_2$	Calcium chloride
$MgCl_2$	Magnesium chloride
NaCl	Sodium chloride
$C_2H_3KO_2$	Potassium acetate
$CHKO_2$	Potassium formate
LiCl	Lithium chloride
NH_3	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

Ethanol

Library LibC2H5OH

Formulation of
Schroeder et al. (2014)

Methanol

Library LibCH3OH

Formulation of
de Reuck and Craven (1993)

Propane

Library LibPropane

Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ **Library LibD4**

Decamethylcyclopentasiloxane $C_{10}H_{30}O_5Si_5$ **Library LibD5**

Tetradecamethylhexasiloxane $C_{14}H_{42}O_5Si_6$ **Library LibMD4M**

Hexamethyldisiloxane $C_6H_{18}OSi_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $C_{12}H_{36}O_6Si_6$ **Library LibD6**

Decamethyltetrasiloxane $C_{10}H_{30}O_3Si_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $C_{12}H_{36}O_4Si_5$ **Library LibMD3M**

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ **Library LibMDM**

Formulation of Colonna et al. (2008)

Nitrogen and Oxygen

**Libraries
LibN2 and LibO2**

Formulations of Span et al. (2000)
and Schmidt and Wagner (1985)

Hydrogen

Library LibH2

Formulation of
Leachman et al. (2009)

Helium

Library LibHe

Formulation of
Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**

Isopentane C_5H_{12} **Library LibC5H12_Iso**

Neopentane C_5H_{12} **Library LibC5H12_Neo**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**
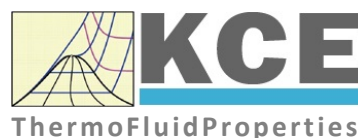
Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide H_2S **Library LibH2S**

Nitrous oxide N_2O **Library LibN2O**

Sulfur dioxide SO_2 **Library LibSO2**

Acetone C_3H_6O **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

KCE

ThermoFluidProperties

For more information please contact:

KCE-ThermoFluidProperties UG & Co. KG
Prof. Dr. Hans-Joachim Kretzschmar
Wallotstr. 3
01307 Dresden, Germany

Internet: www.thermofluidprop.com
Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

The following thermodynamic and transport properties can be calculated[a]:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity v
- Thermal conductivity λ
- Prandtl number Pr
- Thermal diffusivity a

Backward Functions

- $T, v, s\ (p,h)$
- $T, v, h\ (p,s)$
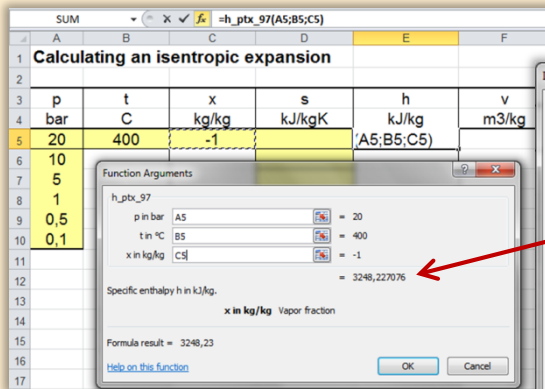- $p, T, v\ (h,s)$
- $p, T\ (v,h)$
- $p, T\ (v,u)$

Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

[a] Not all of these property functions are available in all property libraries.

www.thermofluidprop.com

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www.thermofluidprop.com

Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Hochschule **Zittau/Görlitz**
UNIVERSITY OF APPLIED SCIENCES

Add-In FluidEXL*Graphics* for Excel®

Choosing a property library and a function
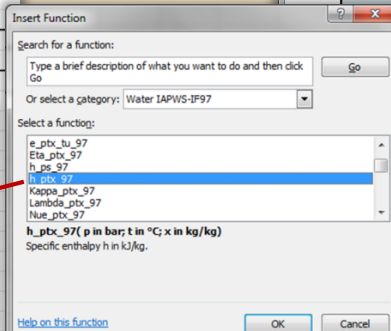
Displaying the calculated values in diagrams

Menu for the input of given property values
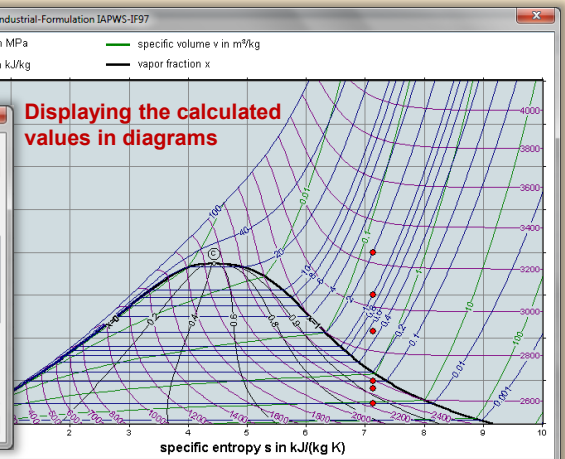
Add-On FluidMAT for Mathcad®
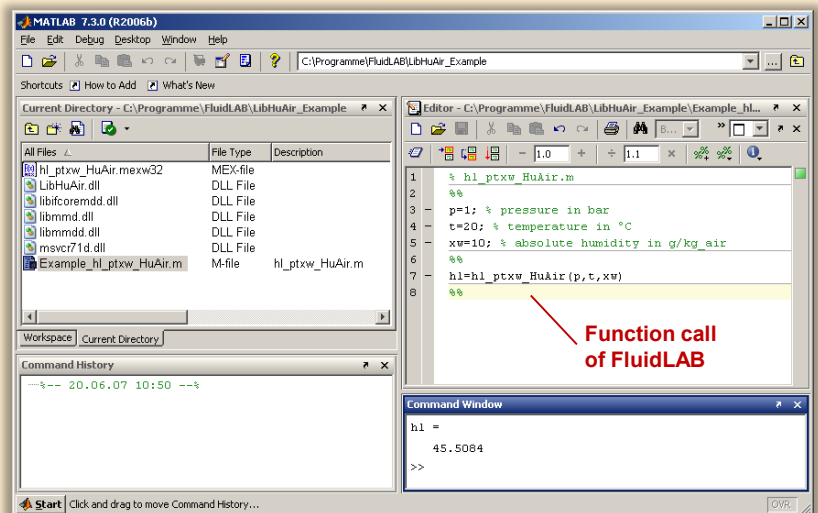## Add-On FluidPRIME for Mathcad Prime®

The property libraries can be used in Mathcad® and Mathcad Prime®.
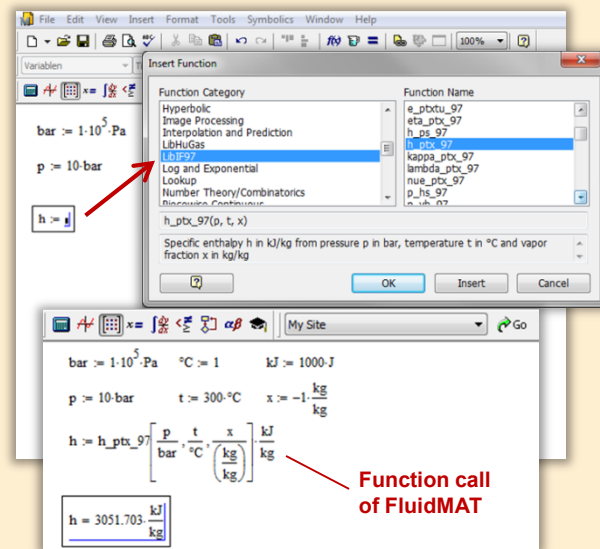
Function call of FluidMAT

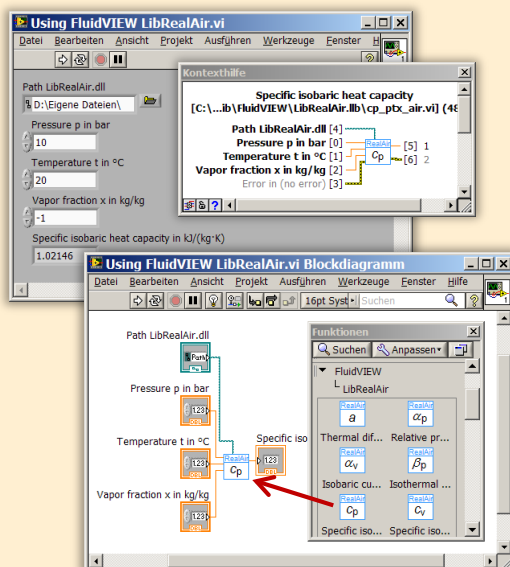## Add-On FluidLAB for MATLAB® and SIMULINK®

Using the Add-In FluidLAB the property functions can be called in MATLAB® and SIMULINK®.

Function call of FluidLAB
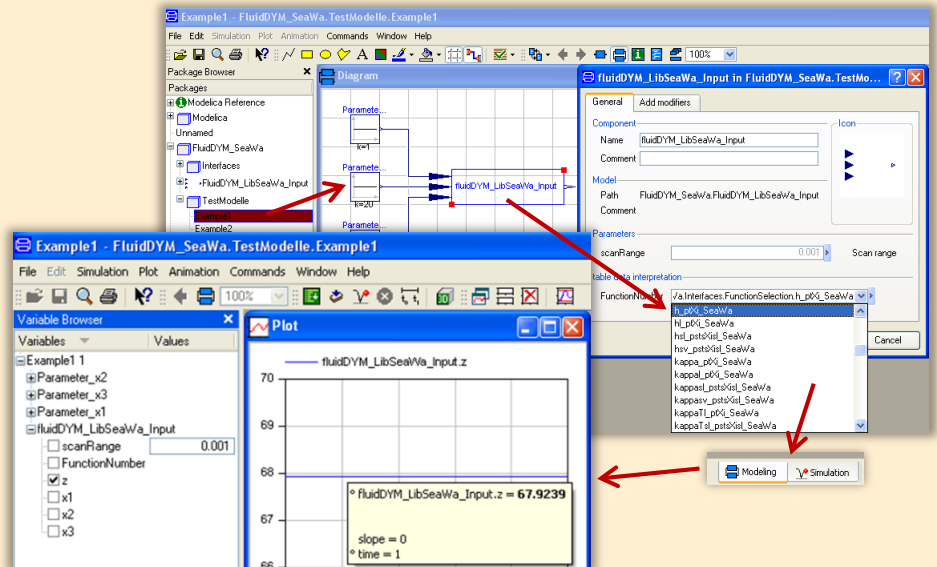

Add-On FluidVIEW for LabVIEW™

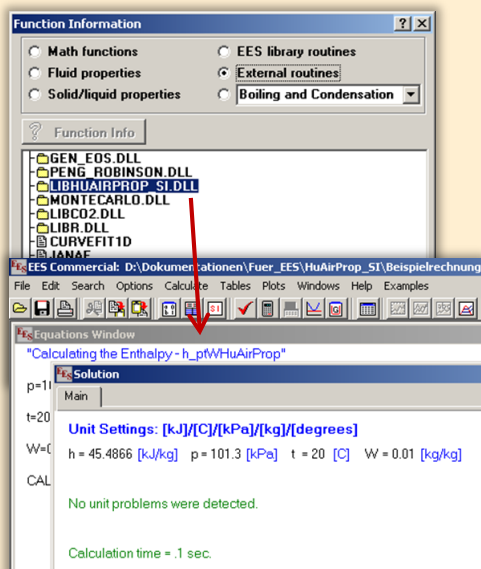The property functions can be calculated in LabVIEW™.

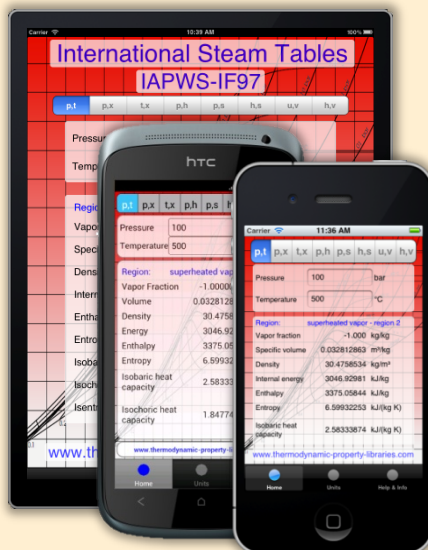## Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

The property functions can be called in DYMOLA® and SimulationX®.

Add-On **FluidEES** for Engineering Equation Solver®

App International Steam Tables for iPhone, iPad, iPod touch, Android Smartphones and Tablets

Online Property Calculator at **www.thermofluidprop.com**

Property Software for Pocket Calculators

FluidCasio

fx 9750 G II

CFX 9850
fx-GG20

CFX 9860 G
Graph 85

ALGEBRA
FX 2.0

FluidHP
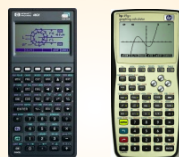
HP 48   HP 49

FluidTI

TI Nspire CX CAS
TI Nspire CAS

TI 83
TI 84
TI 89

TI Voyage 200

TI 92

For more information please contact:
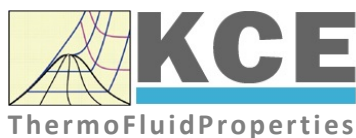
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ThermoFluidProperties

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Email: info@thermofluidprop.com
Phone: +49-351-27597860
Mobile: +49-172-7914607
Fax: +49-3222-1095810

The following thermodynamic and transport properties[a] can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® (EES), DYMOLA® (Modelica), SimulationX® and LabVIEW™:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity v
- Thermal conductivity λ
- Prandtl number Pr
- Thermal diffusivity a

Backward Functions

- $T, v, s\ (p,h)$
- $T, v, h\ (p,s)$
- $p, T, v\ (h,s)$
- $p, T\ (v,h)$
- $p, T\ (v,u)$

Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

[a] Not all of these property functions are available in all property libraries.

www.thermofluidprop.com

5. References

[1]   Colonna, P.; Nannan, N. R.; Guardone, A.;Lemmon, E. W.
        Multiparameter equations of state for selected siloxanes
        Fluid Phase Equilibria, 244, (2006) S. 193-211

[2]   Chung, T. H.; Ajlan, M.; Lee, L. L.; Starling, K. E.
        Generalized multiparameter correlation for nonpolar and polar fluid transport properties
        Industrial & Engineering Chemistry Research, 27, (1988) pp. 671-679

[3]   Poling, B. E.; Prausnitz, J. M.; O'Connel, J. P.
        The Properties of Gases and Liquids
        McGraw-Hill, New York, 5th Edition, 2001, Chapter 9.40, 10.23

[4]   Olchowy, G. A.; Sengers, J. V.
        A simplified representation for the thermal conductivity of fluids in the critical region
        International Journal of Thermophysics, 10, (1989) pp. 417-426

6. Satisfied Customers

Period from 2018 to 2022

The following companies and institutions use the property libraries:

- FluidEXL*Graphics* for Excel® incl. VBA

- FluidLAB for MATLAB® and Simulink

- FluidMAT for Mathcad®

- FluidPRIME for Mathcad Prime®

- FluidEES for Engineering Equation Solver® EES

- FluidDYM for Dymola® (Modelica) and SimulationX®

- FluidVIEW for LabVIEW™

- FluidPYT for Python

- FluidJAVA for Java

- DLLs for Windows Applications

- Shared Objects for Linux

- Shared Objects for macOS.

2022

ASTG, Graz, Austria	12/2022
Wandschneider + Gutjahr, Hamburg	
RWE Supply & Trading, Essen	11/2022
Stadtwerke Rosenheim	
CEA, Saclay, France	10/2022
RWE Supply & Trading, Essen	
SEEC Saudi Energy Efficiency Center, Riyadh, Saudi Arabia	
MAN, Copenhagen, Denmark	
Hermeler & Partner Consulting Engineers, Sassenberg	09/2022
Envi Con, Nürnberg	
Drill Cool Systems, Bakersfield CA, USA	
RWE Supply & Trading, Essen	
Maerz Ofenbau, Zürich, Switzerland	
Saale Energie, Schkopau	
ERGO, Dresden	
Mainova, Frankfurt/Main	
Bundeswehr, Koblenz	08/2022
RWE Supply & Trading, Essen	
Grenzebach Corporation, Newnan GE, USA	
AGRANA, Gmuend, Austria	07/2022
MIBRAG, Zeitz	
Hochschule Niederrhein, Krefeld	
ULT, Löbau	06/2022
LEAG, Cottbus	
VPC Group, Vetschau	

Wärme, Hamburg
ILK, Dresden
Stricker IB, Küssnacht a. Rigi, Switzerland
LEAG, Cottbus   05/2022
RWE Supply & Trading, Essen
IGT Tomalla, Kreuztal
B+T Engineering, Dübendorf, Switzerland
Stricker IB, Küssnacht a. Rigi, Switzerland
Vogelsang & Benning, Bochum   04/2022
Frischli, Rehburg-Loccum
BPS Consulting, Sprenge   03/2022
HS Hannover, Maschinenbau & BioVT
M+M Turbinentechnik, Bad Salzuflen
Uni. Strathclyde, Glasgow, UK   02/2022
Delta Energy Group, Jiaozhou City, Qingdao, China
Wetzel IB, Guben
Wijbenga, PC Geldermalsen, The Netherlands
Voith Paper, Heidenheim
HS Zittau/Görlitz, Maschinenwesen   01/2022
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Webb Institute, Glen Cove NY, USA
TU Berlin, Umweltverfahrenstechnik
SachsenEnergie, Dresden
Doosan, Chang-won-si, Gyeongsangnam-do, South Korea
KW3, LH Veenendaal, The Netherlands
Université du Luxembourg, Esch-sur-Alzette
Enseleit IB, Mansfeld
Caliqua/Equans, Zürich, Switzerland
Rudnick & Enners, Alpenrod

2021

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PPCHEM, Hinwil, Switzerland
KW3, The Netherlands
BASF Ludwigshafen
Air-Consult, Jena
Sjerp & Jongeneel, RB Zoetermeer, The Netherlands   11/2021
Maerz Ofenbau, Zürich, Switzerland
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Therm, South Africa
RWE Supply & Trading, Essen
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RWE Supply & Trading, Essen
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SachsenEnergie, Dresden
BSH Hausgeräte, Berlin

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AKM Industrieanlagen, Haltern	
Drill Cool Systems, Bakersfield CA, USA	
Siemens Energy Global, Erlangen	07/2021
Wulff & Umag, Husum	
Planungsbüro Waidhas, Chemnitz	
Burkhardt Energie Technik, Mühlhausen	
Lücke IB, Paderborn	06/2021
TU Dresden, Energieverfahrenstechnik	
Wärme, Hamburg	
AL-KO Therm, Kötz	
PCK Raffinerie, Schwedt	
Vogelsang & Benning, Bochum	05/2021
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VPC Group, Vetschau	
AVG, Köln	04/2021
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Marty IB, Oberwil, Switzerland	
HypTec, Lebring, Austria	
Lopez IB, Getxo, Bizkaia, Spain	03/2021
GM Remediation Systems, Leoben, Austria	
Jager Kältetechnik, Osnabrück	
T&M Automation, GR Leidschendam, The Netherlands	
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Beuth Hochschule für Technik, Berlin	
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ETABO Bochum	
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thermofin, Heinsdorfergrund	
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ETA Energieberatung, Pfaffenhofen	
Enex Power, Kirchseeon	

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Stellenbosch University, South Africa	

University De France-COMTe, France
RWE, Essen
STEAG, Herne
Isenmann Ingenierbüro
University of Stuttgart, ITLR, Stuttgart
Norsk Energi, Oslo, Norway
TGM Kanis, Nürnberg
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RWE, Essen
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Hochschule Zittau/Görlitz, Maschinenwesen
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2Meyers Ingenieurbüro, Nürnberg
FELUWA, Mürlenbach
Stadtwerke Neuburg
Caverion, Wien, Austria
GMVA Niederrhein, Oberhausen
INWAT Lodz, Poland
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CEA Saclay, France
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